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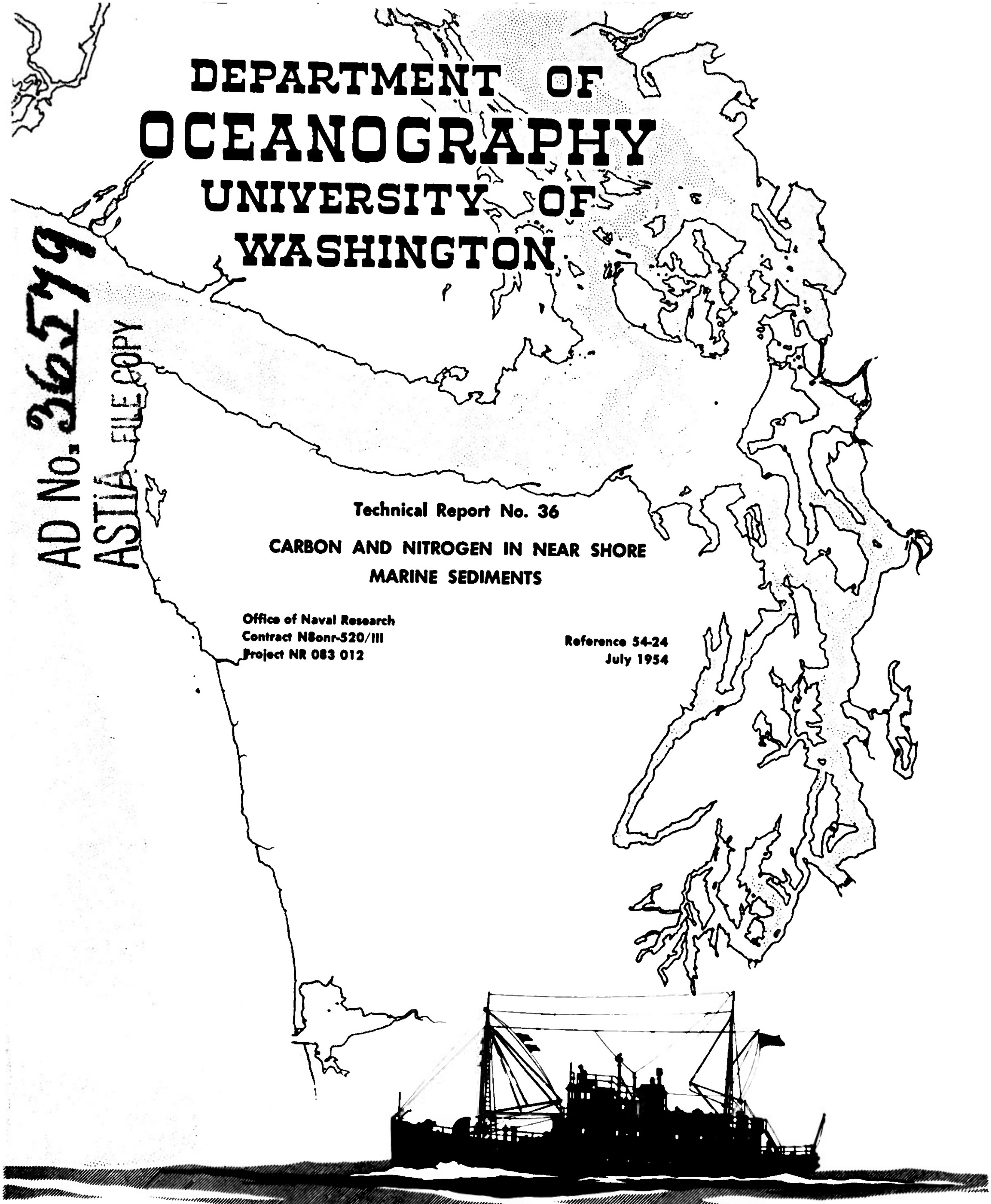

Technical Report No. 36

CARBON AND NITROGEN IN NEAR SHORE MARINE SEDIMENTS

Office of Naval Research
Contract N8onr-520/III
Project NR 083 012

Reference 54-24
July 1954

SEATTLE 5, WASHINGTON

UNIVERSITY OF WASHINGTON DEPARTMENT OF OCEANOGRAPHY
(Formerly Oceanographic Laboratories)
Seattle, Washington

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by

Richard G. Bader

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R H Fleming
Richard H. Fleming
Executive Officer

ABSTRACT

The carbon and nitrogen content of marine sediments is associated with processes such as rates of sedimentation, and environmental aspects of deposition and diagenesis. Information on the distribution of these elements is also pertinent to the evaluation and reconstruction of past environments. It is thus necessary that we have a more thorough understanding of the relationship between carbon and nitrogen in sedimentary materials.

The logarithmic relationship of carbon and nitrogen for 67 samples of near shore marine sediments, both surface and subsurface has been examined. The results are compared using data from various sources. Carbon and nitrogen show an approximately logarithmic linear functional relation. For both surface and subsurface samples the statistical C/N ratio may increase or decrease with increasing organic content. The slopes of the least squares lines, representing this relationship, range from 0.09 to the vertical. Sediments obtained from a Maine Fjord indicate that the carbon-nitrogen association for surface and subsurface samples are quite different. The organic supply and environment of organic decomposition appear to be the primary factors controlling the ratio of carbon to nitrogen loss. The particular type of relationship between carbon and nitrogen in marine sediments varies considerably. Consequently data from different areas must be treated separately.

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INTRODUCTION

In the many studies of marine sedimentary organics, emphasis is placed upon the carbon-nitrogen ratio. Trask (1932), Waksman (1933), Grippenberg (1934), Wiseman and Bennett (1940), Mohamed (1949) and Arrhenius (1950) are but a few of the contributors to information concerning the carbon-nitrogen relationship in marine sediments. The general consensus of opinion, as pointed out by Arrhenius, is that the source of the organic matter is the major factor to consider. He then expressed a personal opinion that mineral matter dilution may quantitatively affect the microbiological decomposition thus becoming the controlling factor with respect to carbon and nitrogen concentrations.

In view of the variations in the data and opinions of other investigators all information on the relationship between carbon and nitrogen in sedimentary material is of value. Additional data may assist in understanding some of the details concerning the role of organic matter in the sedimentary diagenetic processes, and its usefulness in paleo-ecologic reconstructions. The carbon and nitrogen data presented in this report were obtained from a total of 67 marine sediment samples from the near shore regions of the Gulf of Maine and Puget Sound. Forty-four samples represent surface sediments, while 23 are subsurface samples from 13 cores. The carbon content was determined by a semimicro dry combustion method. The nitrogen, by the standard micro-Kjeldahl method.

CARBON AND NITROGEN IN SURFACE SEDIMENTS

The carbon concentrations in the 44 surface samples ranged from 4.74% to 0.24%, with a mean of 1.61%. The nitrogen content varied between 0.58% and 0.02%, the mean being 0.19%. The results obtained from analysis of the individual surface samples are presented in Table I.

In order to readily compare these data with those of other published studies, the carbon and nitrogen relationships are presented in Figure 1 on a logarithmic basis. These two variables apparently have an approximate logarithmic linear functional relation. The slope of the least squares line is about 0.91. This indicates a slight statistical decrease in the C/N ratio with increasing organics. The data as given in Table I shows however, that individually the C/N ratio may deviate widely from the statistical mean.

In comparing the statistical line as shown in Figure 1 with some of the published information there is both close correspondence and wide variation. Figure 2 compares the data of various authors as given by Arrhenius (1950). The data of this investigation corresponds closely with that of Waksman (1933) and Grippenberg (1934). The approximate slope of the mean line calculated from Waksman's data is 1.11; the slope of the line derived from Grippenberg's analyses is about 0.86. The former illustrates a slight increase in C/N ratio with increasing organics, the latter a decrease. The 417 pairs of analyses plotted by Arrhenius (1950) indicate an approximate slope of 1.28.

These, and especially the Wiseman and Bennett data (slope of 0.67) differ the most from the surface samples analyzed for this study.

TABLE I

CARBON AND NITROGEN IN SURFACE SAMPLES

Sample No.	% Carbon	% Nitrogen	C/N	Sample No.	% Carbon	% Nitrogen	C/N
1	0.88	0.14	6.2	23	1.82	0.20	9.1
2	1.72	0.22	7.8	24	0.34	0.05	6.8
3	0.52	0.05	10.4	25	0.30	0.04	7.5
4	1.24	0.11	11.1	26	1.96	0.15	13.1
5	0.94	0.13	6.2	27	2.13	0.17	12.5
6	0.42	0.03	14.0	28	1.86	0.18	10.3
7	0.45	0.02	22.5	29	2.12	0.29	7.3
8	0.66	0.10	6.6	30	2.34	0.26	9.0
9	1.02	0.04	25.5	31	1.78	0.21	8.5
10	0.46	0.03	15.3	32	0.26	0.03	8.6
11	0.35	0.04	8.7	33	1.38	0.07	19.7
12	1.74	0.28	6.2	34	0.34	0.03	11.3
13	1.15	0.14	8.2	35	0.87	0.35	2.5
14	0.49	0.06	8.2	36	3.17	0.25	12.7
15	4.12	0.36	11.4	37	0.24	0.02	12.0
16	4.74	0.49	9.7	38	3.90	0.40	9.7
17	4.12	0.40	10.3	39	0.95	0.13	7.3
18	3.12	0.50	6.2	40	0.29	0.03	9.7
19	2.97	0.58	5.1	41	1.02	0.09	10.3
20	2.66	0.33	8.1	42	1.96	0.22	7.9
21	2.94	0.35	8.4	43	1.62	0.19	8.5
22	2.11	0.29	6.3				

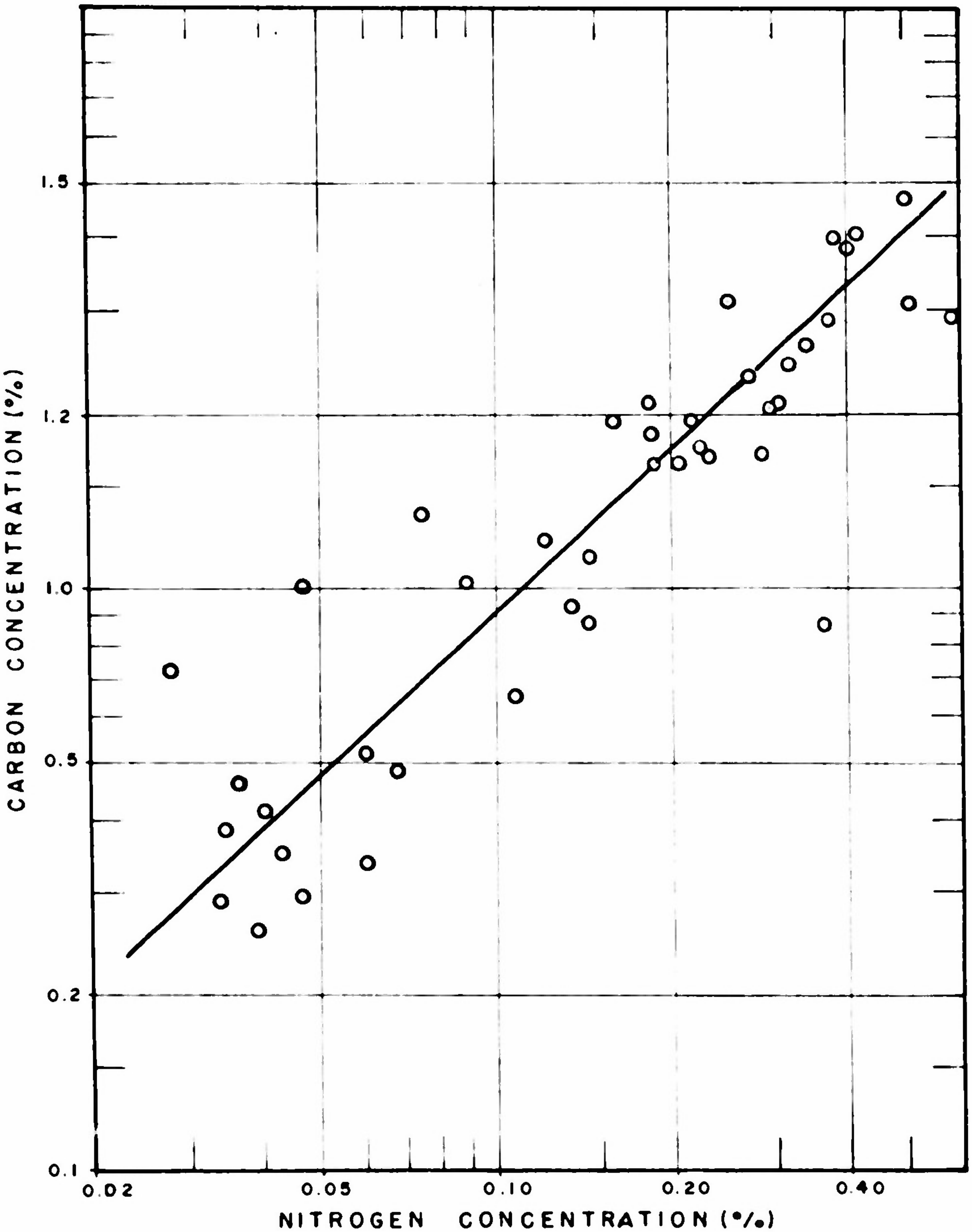

FIGURE 1. Carbon-nitrogen relations for 44 surface samples of marine sediments from the Gulf of Maine and Puget Sound.

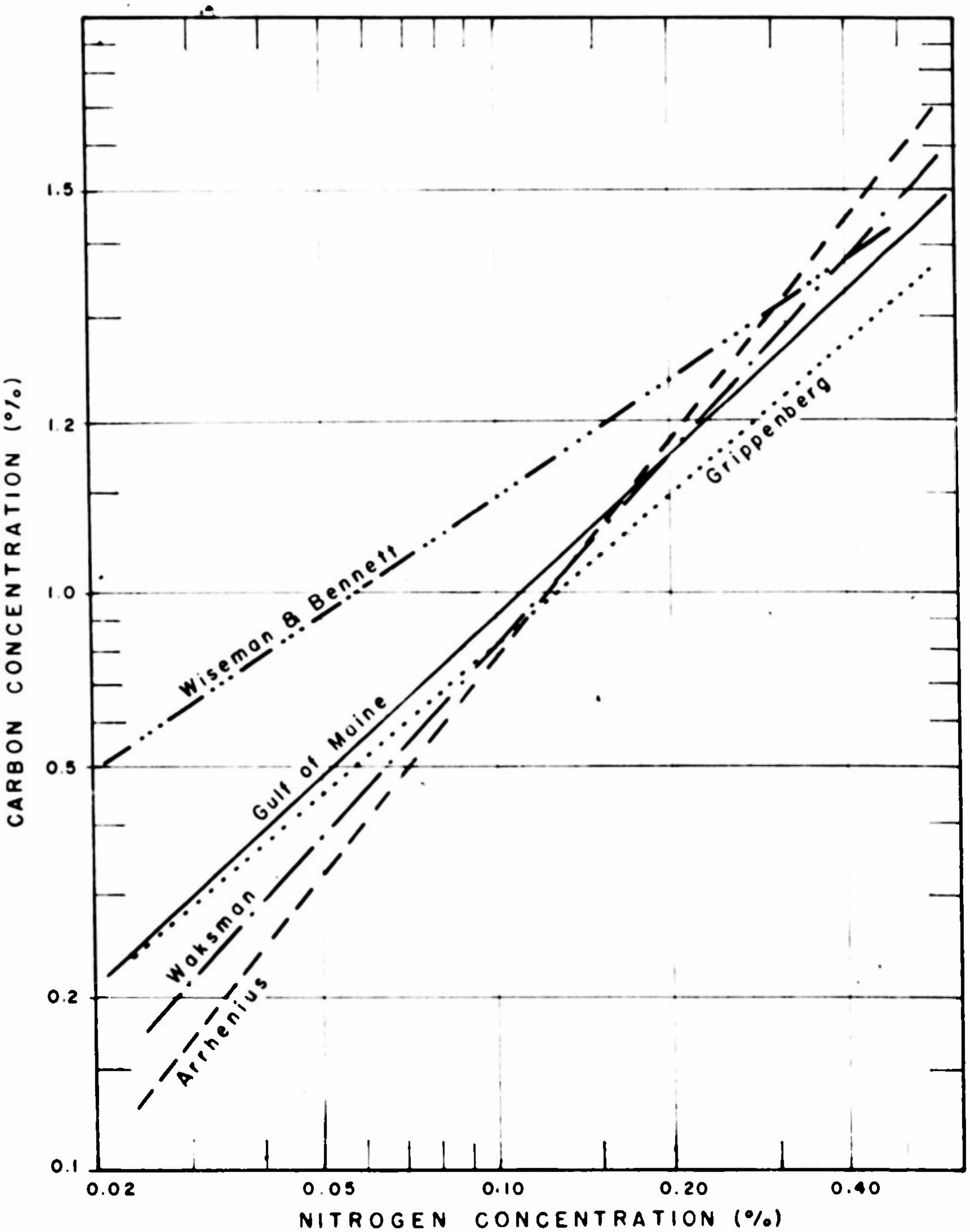

FIGURE 2. Comparison of statistical relations of carbon and nitrogen in marine sediments from various sources.

CARBON AND NITROGEN IN SUBSURFACE SEDIMENTS

In conjunction with the surface sample investigation, the carbon and nitrogen concentrations were determined at various subsurface levels in 13 cores. The data obtained from each core sample is tabulated in Table II. Cores 1 through 9 inclusive represent a single fjord environment off the coast of Maine. Cores 10 through 13 were taken in Puget Sound.

Figure 3 illustrates the carbon-nitrogen relations as expressed logarithmically for the Maine fjord samples. The points representing the surface and subsurface samples for each core are connected by a line. The point on the extreme right for each core represents the surface sample; each succeeding subsurface sample decreases in carbon and nitrogen. From this figure and the table it can be seen that there is an uninterrupted decrease in the organic material with increasing depth. The particle size characteristics of the inorganic fraction are constant throughout each core with median diameters of about 0.007mm. In view of the location of the samples, the uniformity of inorganic particle size and the steadily decreasing organic concentrations, it may be assumed that radical depositional environment changes have probably not occurred in the time represented by the samples. The slopes of the lines representing the logarithmic functional relationship of carbon and nitrogen for each core range from 0.09 to 0.72 with a mean of 0.36.

Figure 4 compares the Maine fjord surface and subsurface samples. The line of best fit for the 12 surface samples in the fjord is essentially the same as the established line for all Gulf of Maine samples as given in Figure 1. The difference in slope between the surface and subsurface samples is obvious.

TABLE II

CARBON AND NITROGEN IN CORE SAMPLES

Sample No.	Depth (cm)	% Carbon	% Nitrogen	C/N	Sample No.	Depth (cm)	% Carbon	% Nitrogen	C/N
15	0	4.13	0.36	11.4	21	0	2.94	0.35	8.4
15a	20	2.84	0.20	14.2	21a	20	2.77	0.34	8.1
15b	47	2.66	0.16	16.6	21b	50	2.54	0.29	8.8
16	0	4.74	0.49	9.7	22	0	2.11	0.29	6.3
16a	20	4.54	0.28	16.2	22a	40	1.97	0.24	8.2
16b	42	4.42	0.24	18.4					
					23	0	1.82	0.20	9.1
17	0	4.12	0.40	10.3	23a	37	1.56	0.14	11.1
17a	46	3.63	0.26	14.0					
					41	0	1.02	0.09	11.3
18	0	3.12	0.50	6.2	41a	115	0.74	0.08	9.3
18a	39	2.70	0.35	7.7	41b	213	0.78	0.08	9.7
19	0	2.97	0.58	5.1	42	0	1.96	0.22	8.9
19a	9	2.62	0.45	5.8	42a	8	1.56	0.22	7.1
19b	42	2.44	0.31	7.9	42b	74	2.38	0.23	10.3
					42c	150	2.00	0.22	9.1
20	0	2.66	0.33	8.1					
20a	20	2.58	0.20	12.9	43	0	1.62	0.19	8.5
20b	30	2.59	0.26	9.9	43a	26	1.35	0.17	7.9
					44a	155	2.19	0.23	9.5
					44b	246	1.11	0.21	5.3

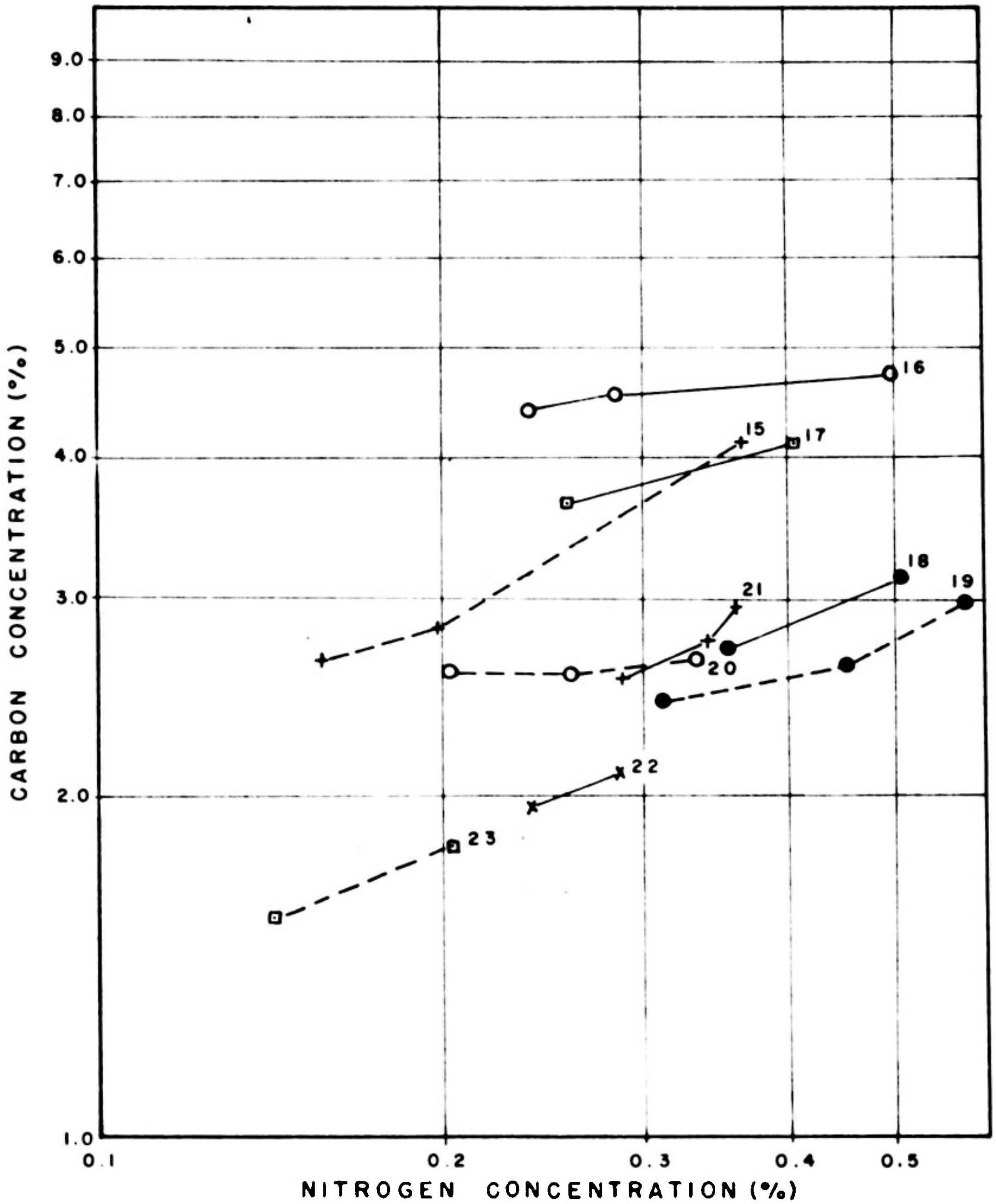

FIGURE 3. Carbon and nitrogen relations in cores from Maine Fjord. Right most point of each core represents the surface sample. Each subsequent point is a successive subsurface sample.

The core samples from Puget Sound are indicative of diverse environmental conditions with time. This is shown by marked particle size variations and abrupt changes in the organic content at various depths in the cores. The situation in this area is thus more complex than in the Maine fjord. The slopes of the lines representing the logarithmic functional relationship of carbon and nitrogen for each core range from 1.80 to the vertical, with a mean of 3.49.

In order to further illustrate the complexity of the situation the results of other investigations are included. In some instances the carbon-nitrogen relations with depth were not directly considered by the authors. The subsurface data from the Gulf of Maine area and Puget Sound is presented in Figure 5 and compared with information from the following four sources:

Trask (1932) presented data on the carbon and nitrogen in some cores from the Channel Islands off the coast of California. By plotting the logarithmic carbon and nitrogen relations for 18 cores it was found that the slopes of the resulting lines arranged themselves into four groups. Group I consists of six cores with slopes ranging from 0.26 to 0.57 with an average of 0.44. Group II contains five cores the slopes of which range from 0.78 to 1.07 with a mean value of 0.89. Group III consists of five cores ranging in slope from 1.37 to 1.60; the average is 1.45. The two cores in Group IV have very steep slopes of 7.11 and 57.29; the average slope as calculated from their angles is 14.00. Unfortunately, size analysis data for all samples are not available for comparison.

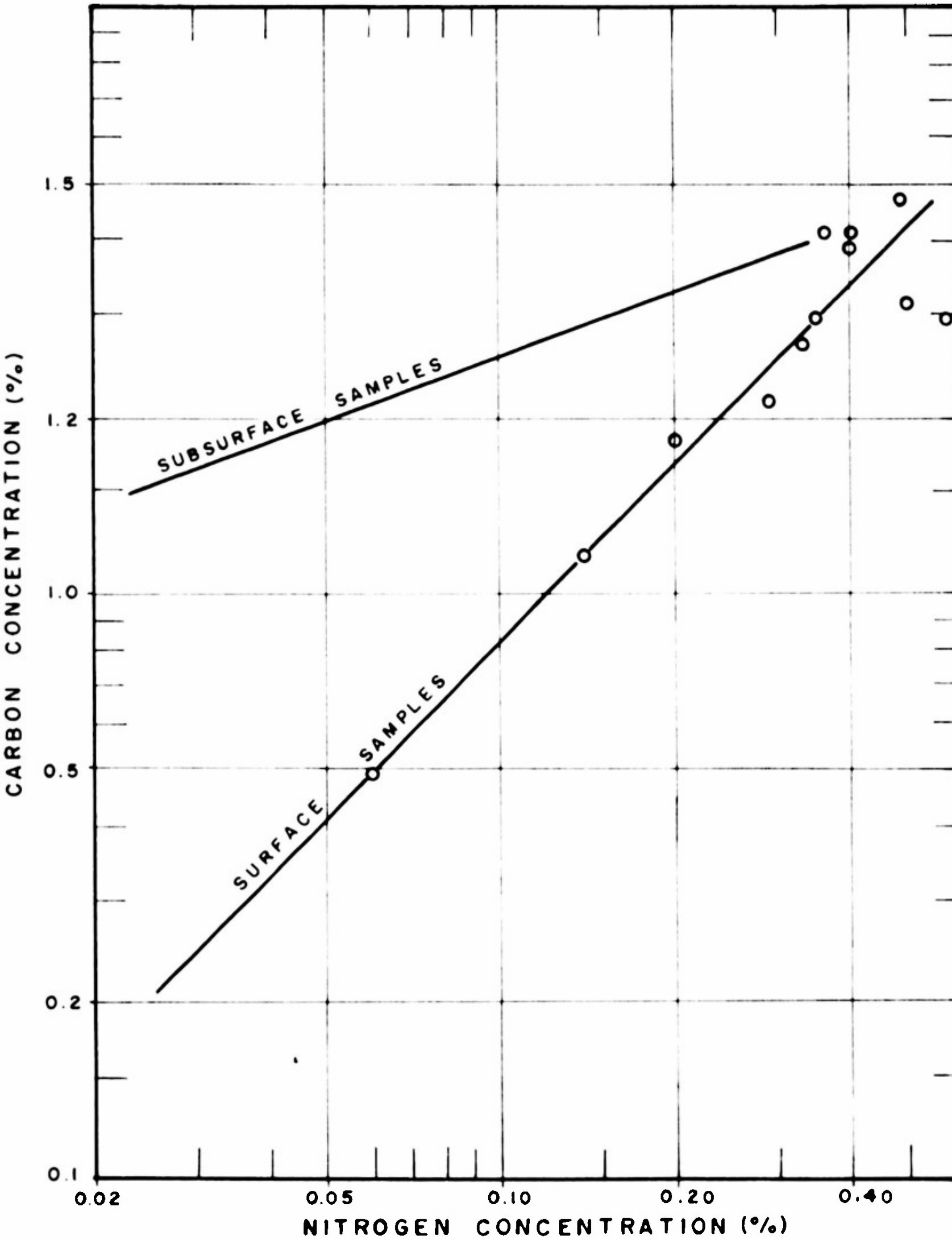

FIGURE 4. Comparison of carbon and nitrogen relations in surface and subsurface samples from Maine Fjord.

Waksman (1933) obtained two cores from the Gulf of Maine which show with increasing depth relatively uniform particle sizes and also a steady decrease in organic matter. A third core acquires these characteristics at a subsurface level of about 35 cm. Both of these factors, present also in the nine Gulf of Maine cores used in this study, indicate a relatively stable depositional environment. The slopes of the lines representing the logarithmic relation of carbon and nitrogen for these cores is 0.14, 0.27, and 0.93. The mean value is 0.44. Waksman also presented information on the carbon and nitrogen for a single core from the vicinity of Spitzbergen. The average slope of the carbon-nitrogen line is 0.75.

Emery and Rittenberg (1952) presented some information on the carbon and nitrogen content of subsurface samples from the Channel Island region of California. From their data it was found that the slopes of the carbon-nitrogen lines of each core fell into two groups. Group I consists of four cores with slopes ranging from 0.46 to 0.62 with an average of 0.55. Group II is composed of six cores with slopes ranging from 0.87 to 1.96 for an average of 1.19. Marked indications of environmental changes with time are in evidence in these samples since both particle size and organic content have appreciable vertical changes.

Arrhenius (1952) shows that for clays in the North Equatorial Pacific, the carbon-nitrogen ratio decreases downward, carbon being lost more rapidly than nitrogen. Under these conditions the resultant slope of any statistical logarithmic line must be greater than one.

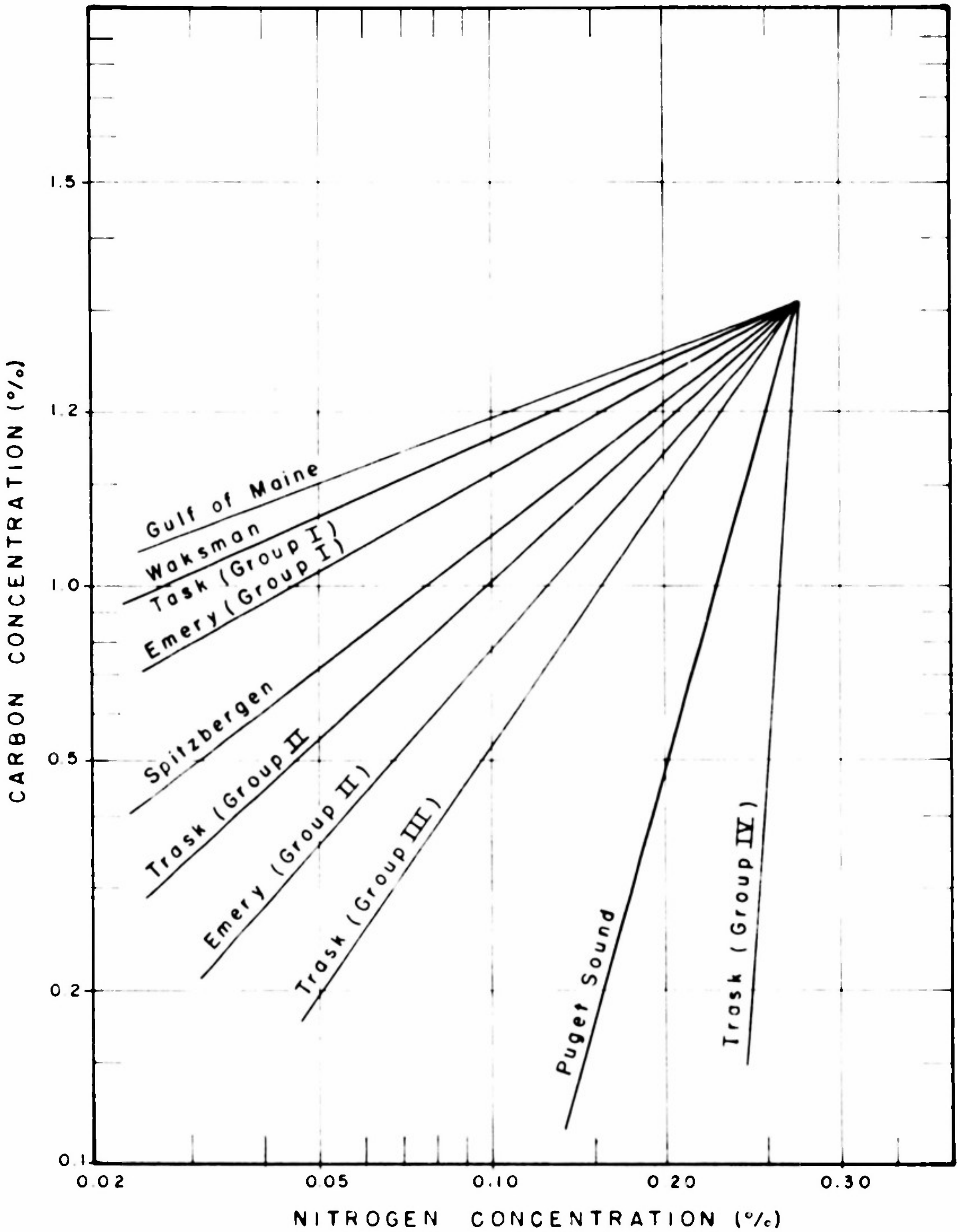

FIGURE 5. Comparison of subsurface carbon and nitrogen data from various sources. The point of origin represents the average surface carbon and nitrogen content for all cores.

CONCLUSIONS

(1) From the available data obtained from various regions the association of carbon and nitrogen exhibits wide differences. The C/N ratio may have a direct or indirect relation with both increasing or decreasing organic material.

(2) The slopes of the statistical lines, representing an approximate logarithmic function, show quite a different relationship between the carbon and nitrogen for surface and subsurface samples in a single area (Fig. 4). This can be attributed to environmental control. Surface samples are intimately associated with both supply and decomposition of the organic material. The subsurface sediments are essentially isolated from continuous organic supply; decomposition is the primary active factor. Anaerobic conditions exist both on and below the surface of the fjord sediments, thus other factors, possibly of a biochemical and microbiological nature, may control the ratio of carbon to nitrogen loss.

(3) From the data presented in Figure 5 it is apparent that the general subsurface anaerobic environment may produce both increasing or decreasing C/N ratios with increasing depth in the sediment. This may be due to local environmental conditions and/or to differences in organic supply.

(4) Though the depositional and post-depositional environment of organic decomposition are of primary importance in regulating the C/N ratio, the type of organic material supplied to the sediments must also

be seriously considered. A sediment receiving a high proportion of lignin has the possibility of developing an abundance of ligno-protein complexes via bacterial activity. These complexes are extremely resistant to decay, and their formation, as controlled in part by the organic supply, may well be associated with the relation between carbon and nitrogen, particularly evident in subsurface sediments.

(5) General conclusions as to the type of relationship between carbon and nitrogen in both surface and subsurface marine sediments from scattered areas cannot be drawn. Each area must be evaluated as a single entity.

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